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ABSTRACT

The research goal was to identify factors affecting mathematices participation and achievement in adolescents, and to offer explanations for sex differences in mathematics behavior from adolescence onward. Subjects (n=1605) were Afrikaans-speaking seventh and ninth grade students, 80 percent of whose parents also participated. Students were randomly selected after stratification by sex/rural-urban location. Measuring instruments included standardized aptitude tests, mathematics achievement tests and questionnaires developed specially for this study, and translated American questionnaries. Marked sex differences favoring males were found for actual, as well as for intended mathematics participation. No sex differences in overall mathematics achievement were found for early adolescents or adolescents, nor for twelfth grade students in final school mathematics examinations. Mathematics olympiad data and final school results indicate substantial sex differences in favor of males at very high achievement levels. Sex differences in spatial visualization were found for adolescents only and substantial correlations between spatial abilities/mathematics achievement were found. Although adolescent males were signficantly more positive toward mathematics than females, this was not true of younger male students, except in their perception of the personal usefulness of mathematics. Males, including fathers, stereotyped mathematics as a male domain. Non-cognitive variables correlated substantially with mathematics achievement of ninth grade females. Further intention of ninth grade females to continue mathematics was accurately (R=.65) predicted by social, affective, and attitudinal variables, with parental encouragement being a major influence. (JM)

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SEX DIFFERENCES IN MATHEMATICS ACHIEVEMENT AND PARTICIPATION

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This study concerns the explanation of sex differences that typically occur from adolescence onwards and favour males in achievement and participation in mathematics. In the absence of conclusive biological evidence, social, emotional and attitudinal factors were investigated in this regard. The subjects were 1605 Afrikaans-speaking seventh and ninth grade students whose parents were also invited to participate. Cognitive measures included mathematics achievement and several aptitude tests. Also measured were attitudinal variables such as confidence and enjoyment of mathematics, perception of the attitudes of significant others towards self, personal and general usefulness of mathematics and the stereotyping of mathematics. For ninth graders, but not for seventh graders, significant differences ($p < .0001$) favouring males were found in spatial abilities and several non-cognitive variables. In contrast to males, the intention of ninth grade females to continue their participation in mathematics was accurately predicted by non-cognitive variables.

Adequate preparation in mathematics has aptly been called the "critical filter" in the job market. As a result of technological advances and the information explosion, a certain degree of mathematical sophistication has become a prerequisite for most prestigious occupations. It is also to an ever-increasing extent becoming necessary for occupations which have traditionally been regarded as non-mathematical. Students who elect to discontinue their mathematics studies while they are still at school thereby effectively eliminate themselves from the majority of better paid occupations. In a developing country such as the Republic of South Africa where every effort should be made to alleviate the shortage of scientific, research and technical personnel, an obvious starting point is to ensure that as many students as possible complete the mathematics courses offered at school.

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In the USA several options exist for school mathematics. After the eighth grade mathematics is optional and students may choose how many mathematics courses they wish to study, a factor which certainly complicates research on sex differences in achievement. In South Africa mathematics is compulsory until the ninth grade, whereafter students may opt either to discontinue their mathematics studies, or to continue until the twelfth grade at one of two different levels. The choice between higher and standard grade mathematics is normally guided by the teacher on the basis of the student's past achievement. These two courses differ with regard to level or difficulty, rather than to content. Past experience with mathematics should therefore not be a confounding factor when the mathematics achievement and enrollment of males and females is compared. In South Africa the far-reaching decision to discontinue school mathematics is made by 14 to 15 year old adolescents during the ninth grade, which makes it especially important to establish which factors influence their decision during this period.

It has frequently been reported that no or few sex differences in mathematics achievement or ability are evident until the age of about 13, whereafter the performance of females begins to decline in relation to that of males, especially in areas such as problem-solving (Armstrong, 1985; ETS, 1979: Husén, 1967; Maccoby & Jacklin, 1974; Preece, 1979; Wise, 1985; Wood, 1976). At the upper end of the scale it seems that sex differences favouring males are even more pronounced. Benbow and Stanley (1980, 1983) reported sex differences among mathematically gifted students from about the seventh grade, while the ETS (1979) report also confirmed male superiority among the top scorers on the Mathematics SAT. A study of the results of the USA Mathematical Olympiad and the High School Mathematics Contest has revealed that extremely high levels of mathematical performance seem to be very rare among females (Chipman & Thomas, 1985). However, sex differences in high school grades in mathematics are not usually found in the USA.

It is generally accepted that sex differences in mathematics achievement are explained primarily by differences in mathematics course participation (Chipman & Wilson, 1985; Fennema & Sherman, 1977), although it seems that explanations for male superiority among the gifted, such as that indicated by the Johns Hopkins or the Mathematical Olympiad data, have to be found elsewhere. Males are far more likely to enroll in high school mathematics courses than are females (Fennema & Sherman, 1977; Sells, 1978; Wise, Steel & MacDonald, 1979). However, Chipman and Thomas (1985) have shown that at present the difference is not as great as was previously believed, because female enrollment has increased dramatically since the 1960 Project TALENT data was analysed.

In South Africa similar tendencies are found. During 1980 72 percent of the twelfth grade males as against 48 percent of the females in the Transvaal (white population only) studied mathematics. It should be remembered that not all of these students passed mathematics or attained levels of achievement which would have allowed them access to mathematics-related university or technikon courses. The corresponding figures for 1984 were 84 percent for males and 62 percent for females. It is gratifying to note that the position has improved for both sexes, but the fact remains that notable sex differences in school mathematics participation still exist in South Africa.

With regard to achievement, there seem to be no noteworthy sex differences in twelfth grade final mathematics examination results. In 1984 the mean mathematics higher grade percentages (and standard deviations) for the abovementioned population were 53.4 (18.1) for males and 55.5 (16.8) for females. It should be remembered that the females are a select group in comparison with the males, which probably accounts for the females' slightly higher achievement. Among the top scorers, however, males outperform females. During 1982, 4.6 percent of the males as against 3.5 percent of the females scored over 80 percent, whereas the corresponding figures for 1984 were 3.2 percent for

males and 2.6 percent for females. A nationwide mathematics olympiad is arranged yearly for mathematically gifted students. In the period 1966 to 1983 only 12 females gained silver medals as against the 165 silver medals awarded to males. No gold medals have been awarded to females, and in 1983 only six females as against 107 males progressed to the final round of the olympiad. The latter differences cannot be explained by differences in mathematics course participation, because the same curriculum is followed by all mathematics students.

In the absence of conclusive biological evidence to explain sex differences in adolescent mathematics behaviour, it was hypothesized that obtained differences may be ascribed either to a change in the content of mathematics tests, and/or to affective, attitudinal and social factors which come into play during the high school years. It was therefore decided to perform a comprehensive study among Afrikaans-speaking adolescents in the Transvaal to evaluate simultaneously the interaction between variables which have been hypothesized to be significant predictors of mathematics achievement behaviour (Fennema, 1977; Fox, 1977).

Method

Subjects

Seventh grade students were selected to represent the early adolescent group in this study, while ninth grade students were selected to represent the adolescent group. The students were randomly selected from Transvaal schools after stratification by sex and rural-urban location. Thirty-six high schools and 36 primary schools were included in the study. The parents of each student were also invited to participate in the study, and almost 80 percent of them responded. The sample consisted of 824 seventh grade students and 781 ninth grade students. Altogether 1186 fathers and 1320 mothers participated in the study. The mean age on the first day of testing for seventh graders was 12.4 years and for ninth graders 14.4 years. Students were four months older on the second day of testing, which resulted in a small number of students dropping out of the study.

Measuring Instruments

The measuring instruments included standardized aptitude tests, mathematics achievement tests developed specially for this study, translated versions of American questionnaires and questionnaires developed with this study in mind.

Aptitude Tests

Six subtests of the Junior Aptitude Tests (JAT), standardized by the Human Sciences Research Council (HSRC), were used for measuring verbal and nonverbal reasoning, numerical ability and spatial visualization. The JAT was developed in the tradition of the primary mental abilities approach. The subtests were Reasoning (verbally formulated problems including number series, word analogies, arithmetical problems, vocabulary, general logic), Synonyms, Classification (five drawings of known subjects, of which one does not match the others), Number (arithmetical calculations), Spatial 2-D (two-dimensional spatial visualization) and Spatial 3-D (three-dimensional spatial visualization).

Mathematics Achievement Tests

Two mathematics achievement tests, one each for seventh and ninth grades, were developed especially for this study by the HSRC. The tests were based on the students' current mathematics curricula. These tests could not be standardized on other samples and the final selection of items had to be made on the basis of the results of the present study. Even after elimination of the most difficult items, the resulting 30-item test for seventh graders and 25-item test for ninth graders were slightly too difficult.

Mathematics Attitudes Scales

Eleven Likert-type attitude scales were developed and/or translated to measure students' and parents' attitudes to mathematics. The first four scales are similar to the Fennema-Sherman Mathematics Attitude Scales (Fennema & Sherman, 1976) of the same names and were developed by Visser (1983a). Items adapted from

Aiken's E- and V-scales (1974), items from the Fennema-Sherman Scales, and several original items, were included in the final scales.

Confidence Scale. This 15-item scale was developed to measure a subject's confidence versus his/her discomfort, anxiety and uncertainty when dealing with mathematics.

Motivation Scale. A 15-item scale to measure a subject's interest and willingness to become more deeply involved in mathematics, to accept the challenge of mathematics, to do more than is required.

Male Domain Scale. A 15-item scale to measure the extent of the stereotyping of mathematics as a male domain.

General Usefulness Scale. A 10-item scale to measure the extent to which mathematics is regarded as important and useful for society.

Personal Usefulness Scale. A 12-item scale translated from the Fennema-Sherman U Scale to determine the usefulness of mathematics for the self at the present time and for future training, occupations or other activities. Three items were adapted to make it clear that they refer to the self.

Attitude toward Success Scale. A 12-item scale translated from the Fennema-Sherman AS Scale.

Perception of Father's (Mother's, Teacher's) Attitude Scale. Three 12-item scales translated from the Fennema-Sherman F, M and T Scales to measure the perceived interest and encouragement from significant others.

Perception of Male Peer Group's Attitude Scale. A 12-item scale similar to the abovementioned scales which was developed for the purposes of this study.

Importance for "X" Scale. This 15-item scale measures the importance attached by parents to their child's mathematics studies and the degree to which they encourage the child.

Psychometric properties of all the abovementioned measures as found in this study are discussed elsewhere (Visser, 1985).

Procedure

All testing was conducted by experienced test administrators of the education department at the various schools. The aptitude tests and attitude scales were administered during May/June of the academic year, while the mathematics tests were administered four months later to the same students. The attrition rate was fairly low and should not have produced any systematic effects on the large samples. Students took their parents' questionnaires home and returned them to school within one week.

Results

Sex differences in achievement and participation

In the introduction it was shown that marked sex differences favouring males exist as far as school mathematics participation is concerned. It was pointed out that mathematics is compulsory until the ninth grade, whereafter students may discontinue their mathematics studies or continue until the twelfth grade. It is therefore of particular importance to establish which factors influence the student's decision during the ninth grade.

As early as in the seventh grade more males than females have the intention to persist with mathematics until the twelfth grade. Frequencies of students' intended mathematics participation are given in Table 1. A larger proportion of females in ninth grade than in seventh grade intend to discontinue their mathematics studies, but the opposite is true for boys. Whereas the ninth grade percentages are probably realistic for females, judging by the actual figures for 1984 given earlier, it is doubtful that as much as 94 percent of the boys will actually continue with mathematics.

In accordance with the findings of overseas studies, a clear picture did not emerge for sex differences in mathematics achievement over the entire range of the achievement scale. It was shown that males excel at the top end of the scale, but also that males do not usually obtain higher school grades in mathematics.

Table 1

Frequencies of students who intend to continue with mathematics until twelfth grade

Sex	Intention Yes	No	Total
Seventh grade			
Male	352 (90.5%)	37 (9.5%)	389 (100%)
Female	334 (77.9%)	95 (22.1%)	429 (100%)
Total	686	132	818
Ninth grade			
Male	348 (94.1%)	22 (5.9%)	370 (100%)
Female	261 (64.9%)	141 (35.1%)	402 (100%)
Total	609	163	772

In the present study analyses of variance using grade and sex as independent variables were performed on each of the student variables. The respective means and standard deviations are given in Tables 2 and 3. No sex differences were found on the mathematics achievement tests in either of the grades. The achievement tests did not contain enough items to permit comparisons for different branches of mathematics. Furthermore, no sex differences were found in either of the two grades on the computation test, JAT Number.

The lack of sex differences in achievement negated the necessity for the hypothesis that differences from adolescence onwards may be ascribed to a change in the content of mathematics tests for the different grades. Mathematics courses contain less computation in the higher grades, and it has been hypothesized that sex differences in mathematics achievement may be explained by sex differences in spatial orientation and visualization which

Table 2

Means and standard deviations of student variables
for seventh graders

	Male			Female		
	$\bar{X}$	(s)	N	$\bar{X}$	(s)	N
Junior Aptitude Tests (JAT)						
Reasoning	14.1	(4.8)	339	14.7	(4.9)	386
Synonyms	15.1	(5.2)	339	15.7	(5.1)	386
*Classification	21.6	(4.3)	339	19.9	(4.2)	386
Number	11.7	(4.3)	339	12.9	(4.1)	386
Spatial 2-D	24.3	(7.4)	339	22.2	(7.2)	386
Spatial 3-D	18.8	(5.8)	339	17.3	(5.7)	386
Student Questionnaires						
Confidence	55.5	(11.6)	389	53.5	(12.3)	435
Motivation	59.3	(10.1)	389	57.8	(10.5)	435
*Male Domain	49.9	(9.3)	389	55.8	(9.1)	435
General Usefulness	42.3	(5.6)	389	40.8	(6.1)	435
*Personal Usefulness	50.2	(8.0)	389	47.7	(8.6)	435
Attitude toward success	47.9	(6.4)	389	48.1	(6.3)	435
Perception of Father's Attitude	49.8	(7.6)	389	48.5	(7.5)	435
Perception of Mother's Attitude	49.5	(7.2)	389	47.9	(7.4)	435
Perception of Teacher's Attitude	41.2	(6.9)	389	41.1	(7.1)	435
*Perception of Male Peer Group's Attitude	43.3	(5.6)	389	40.8	(5.2)	435
Mathematics Achievement	13.3	(5.1)	323	12.8	(5.1)	374

*Significant differences between male and female, $p < .0001$

Table 3

Means and standard deviations of student variables
for ninth graders

	Male			Female		
	$\bar{X}$	(s)	N	$\bar{X}$	(s)	N
Junior Aptitude Tests (JAT)						
Reasoning	17.9	(4.6)	367	18.1	(4.9)	397
Synonyms	19.5	(4.5)	367	19.7	(4.8)	397
*Classification	24.2	(3.4)	367	22.4	(3.8)	397
Number	15.7	(4.8)	367	16.0	(5.1)	397
*Spatial 2-D	28.2	(6.9)	367	25.7	(7.3)	397
*Spatial 3-D	22.7	(5.3)	367	19.9	(5.9)	397
Student Questionnaires						
*Confidence	54.9	(11.1)	376	50.9	(13.2)	405
*Motivation	58.6	(9.1)	376	55.6	(12.0)	405
*Male Domain	52.1	(8.6)	376	58.3	(8.2)	405
General Usefulness	43.1	(4.3)	376	41.3	(5.4)	405
*Personal Usefulness	51.0	(6.7)	376	46.1	(10.3)	405
Attitude toward success	49.2	(5.9)	376	48.5	(6.8)	405
*Perception of Father's Attitude	50.3	(7.1)	376	46.9	(8.6)	405
*Perception of Mother's Attitude	49.7	(6.6)	376	45.8	(8.8)	405
Perception of Teacher's Attitude	42.3	(6.3)	376	40.4	(7.3)	405
*Perception of Male Peer Group's Attitude	44.7	(5.3)	376	42.4	(5.3)	405
Mathematics Achievement	10.3	(4.4)	328	10.4	(4.9)	351

*Significant differences between male and female, $p < .0001$

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are also typically found from adolescence onwards (Connor & Serbin, 1980; Fennema & Sherman, 1977; Maccoby & Jacklin, 1974). In Tables 2 and 3 it is shown that no sex differences were found for seventh graders on the JAT Spatial 2-D and Spatial 3-D, whereas significant differences favouring males were found for ninth graders. If sex differences had been found on the achievement tests, particularly with regard to certain branches of mathematics, the obtained sex differences in spatial visualization for the ninth grade might have provided an explanation.

No sex differences were found for the verbal tests, JAT Reasoning and Synonyms, but ninth grade males performed significantly better than females on the non-verbal reasoning test, JAT Classification.

Sex differences in attitudinal variables

The means, standard deviations and results of analyses of variance for all the attitudinal variables for students and parents are given in Tables 2, 3 and 4. Seventh and ninth grade males were more inclined than their female counterparts to regard mathematics as personally useful and had a more positive perception of the male peer group's attitude toward themselves as learners of mathematics. They were also more inclined to stereotype mathematics as a male domain. However, on the Confidence, Motivation, Father and Mother Scales significant sex differences favouring males were found only in the older age group.

Although parents agreed on the general usefulness of mathematics, fathers had higher scores than mothers on the other attitudinal variables. Both mothers and fathers regarded mathematics as more important for their sons than for their daughters.

These findings lend support to the hypothesis that developmental changes caused by the environment during adolescence may be partially responsible for sex differences in mathematics behaviour.

Table 4

Means and standard deviations of parent variables

	Father			Mother		
	$\bar{X}$	(s)	N	$\bar{X}$	(s)	N
*Confidence	52.9	(12.8)	1186	45.8	(13.5)	1320
*Motivation	54.7	(10.8)	1186	49.0	(11.2)	1320
*Male Domain	57.2	(8.2)	1186	59.3	(7.8)	1320
General Usefulness	41.7	(5.1)	1186	42.0	(4.9)	1320
**Importance for "X" (where "X" is male)	62.0	(7.3)	559	61.2	(6.8)	622
**Importance for "X" (where "X" is female)	58.5	(9.2)	627	57.2	(9.3)	698

*Significant differences between means of mothers and fathers, $p < .0001$

**Significant differences between means of scores on "Importance for X" - where the difference pertains to the sex of the child referred to by parent, $p < .0001$

Prediction of mathematics participation and achievement

It was decided to use a purely predictive model rather than a 'causal' model for determining the relationships between the various cognitive and non-cognitive variables and the dependent variables, mathematics achievement and mathematics participation.

The correlations between all the study variables and mathematics achievement for each grade and sex are given in Table 5. Table 6 is a similar table of correlations with intended mathematics participation. It was arbitrarily decided to underline all correlations equal to or larger than .40 to enable the reader to distinguish order in the patterns of correlations. Stepwise multiple regression analyses were performed for each grade and sex and the results are reported in Table 7 for mathematics achievement as dependent variable and in Table 8 for intended participation as dependent variable. The variables are reported in the order in which they were entered in the regression equation. Only variables adding at least one percent to the predictable variance are included and the resulting squared multiple correlation coefficients are underlined.

From Table 5 it is clear that cognitive variables are the best predictors of mathematics achievement during the seventh and ninth grades, but that several attitudinal variables and some parent variables correlate highly with the achievement of ninth grade females only. The multiple regression analyses reported in Table 7 confirm these observations. It should be remembered that intercorrelations between predictor variables result in prediction equations which contain variables that do not necessarily correlate most highly with the criterion. The size of the contribution of a variable over and above that of variables already entered in the equation, determines whether the variable is a significant predictor. The order of the predictor variables in Table 7 should therefore not be taken literally, because it is obvious from the given order that the predictor variables intercorrelate. The obtained squared multiple correlation coefficients

Table 5

Correlations between study variables and mathematics achievement for seventh and ninth graders

	Seventh Grade				Ninth Grade			
	Male		Female		Male		Female	
Junior Aptitude Tests								
Reasoning	.60	(287)	.67	(336)	.54	(322)	.65	(344)
Synonyms	.59	(287)	.60	(335)	.46	(322)	.57	(344)
Classification	.25	(287)	.40	(336)	.31	(322)	.38	(344)
Number	.60	(287)	.61	(335)	.64	(322)	.63	(344)
Spatial 2-D	.44	(287)	.47	(336)	.42	(322)	.48	(344)
Spatial 3-D	.50	(287)	.46	(335)	.39	(322)	.51	(344)
Student Questionnaires								
Confidence	.40	(323)	.35	(374)	.35	(328)	.52	(351)
Motivation	.38	(323)	.36	(374)	.27	(328)	.47	(351)
Male Domain	.20	(323)	.43	(374)	.13	(328)	.43	(351)
General Usefulness	.35	(323)	.35	(374)	.19	(328)	.41	(351)
Personal Usefulness	.37	(323)	.37	(374)	.30	(328)	.47	(351)
Attitude toward Success	.31	(323)	.20	(374)	.19	(328)	.23	(351)
Perception of Father's Attitude	.36	(323)	.34	(374)	.22	(328)	.44	(351)
Perception of Mother's Attitude	.37	(323)	.36	(374)	.22	(328)	.42	(351)
Perception of Teacher's Attitude	.23	(323)	.17	(374)	.19	(328)	.38	(351)
Perception of Male Peer Group's Attitude	.24	(323)	.14	(374)	.08	(328)	.19	(351)
Parent Variables								
Confidence (Father)	.06	(243)	.27	(284)	.07	(247)	.20	(266)
Confidence (Mother)	.04	(272)	.07	(324)	.10	(272)	.07	(278)
Motivation (Father)	-.01	(243)	.21	(284)	.03	(247)	.19	(266)
Motivation (Mother)	-.05	(272)	.08	(324)	.04	(272)	.05	(278)
Male Domain (Father)	.19	(243)	.25	(284)	.05	(247)	.26	(266)
Male Domain (Mother)	.18	(272)	.32	(324)	.08	(272)	.41	(278)
General Usefulness (Father)	.14	(243)	.12	(284)	.01	(247)	.13	(266)
General Usefulness (Mother)	.05	(272)	.16	(324)	.02	(272)	.26	(278)
Importance for "X" (Father)	.26	(243)	.28	(284)	.15	(247)	.39	(266)
Importance for "X" (Mother)	.16	(272)	.29	(324)	.26	(272)	.43	(278)

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Table 6

Correlations between study variables and intended mathematics participation for seventh and ninth graders

	Seventh Grade				Ninth Grade			
	Male		Female		Male		Female	
Junior Aptitude Tests								
Reasoning	.19	(339)	.21	(381)	.14	(361)	.41	(394)
Synonyms	.17	(339)	.15	(380)	.07	(361)	.42	(394)
Classification	.07	(339)	.18	(381)	.14	(361)	.28	(394)
Number	.19	(339)	.21	(380)	.21	(361)	.41	(394)
Spatial 2-D	.20	(339)	.21	(381)	.15	(362)	.36	(394)
Spatial 3-D	.17	(339)	.16	(380)	.22	(362)	.38	(394)
Student Questionnaires								
Confidence	.41	(389)	.50	(429)	.30	(370)	.64	(402)
Motivation	.45	(389)	.56	(429)	.31	(370)	.64	(402)
Male Domain	.13	(389)	.29	(429)	.02	(370)	.47	(402)
General Usefulness	.42	(389)	.45	(429)	.17	(370)	.55	(402)
Personal Usefulness	.52	(389)	.59	(429)	.44	(370)	.75	(402)
Attitude toward Success	.18	(389)	.19	(429)	.03	(370)	.28	(402)
Perception of Father's Attitude	.36	(389)	.41	(429)	.27	(370)	.61	(402)
Perception of Mother's Attitude	.37	(389)	.44	(429)	.24	(370)	.62	(402)
Perception of Teacher's Attitude	.19	(389)	.28	(429)	.14	(370)	.38	(402)
Perception of Male Peer Group's Attitude	.19	(389)	.16	(429)	.06	(370)	.29	(402)
Parent Variables								
Confidence (Father)	.09	(292)	.29	(327)	-.08	(263)	.23	(294)
Confidence (Mother)	.06	(324)	.10	(371)	.11	(293)	.15	(319)
Motivation (Father)	.07	(292)	.22	(327)	-.10	(263)	.22	(294)
Motivation (Mother)	.10	(324)	.14	(371)	.10	(293)	.11	(319)
Male Domain (Father)	.06	(292)	.05	(327)	-.03	(263)	.29	(294)
Male Domain (Mother)	.04	(324)	.18	(371)	-.05	(293)	.34	(319)
General Usefulness (Father)	.13	(292)	.15	(327)	.04	(263)	.21	(294)
General Usefulness (Mother)	.14	(324)	.12	(371)	.05	(293)	.34	(319)
Importance for "X" (Father)	.26	(292)	.30	(327)	.06	(263)	.53	(294)
Importance for "X" (Mother)	.37	(324)	.34	(371)	.24	(293)	.61	(319)

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Table 7

Predictive models for mathematics achievement based on stepwise multiple regression analyses utilizing student and parent variables*

Male		Female	
Variable	Squared multiple correlation	Variable	Squared multiple correlation
Seventh Grade			
JAT Reasoning	.37	JAT Reasoning	.49
JAT Number	.45	JAT Number	.56
JAT Synonyms	.49	JAT Synonyms	.60
JAT Spatial 3-D	.51	Perception of Mother's Attitude	.61
Confidence	.52	JAT Spatial 3-D	.62
Motivation (Mother)	.53		
Male Domain (Mother)	.54		
Ninth Grade			
JAT Number	.41	JAT Reasoning	.46
JAT Reasoning	.45	JAT Number	.53
Confidence	.46	Confidence	.58
		JAT Spatial 3-D	.59
		JAT Synonyms	.61

*Only variables adding at least 1 percent to predicted variance are included.

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Table 8

Predictive models for intended mathematics participation based on stepwise multiple regression analyses utilizing student and parent variables*

Male		Female	
Variable	Squared multiple correlation	Variable	Squared multiple correlation
Seventh Grade			
Personal Usefulness	.19	Personal Usefulness	.33
Importance for "X" (Mother)	.24	Confidence	.37
Perception of Father's Attitude	.27	Confidence (Father)	.39
General Usefulness (Mother)	.30	Importance for "X" (Mother)	.41
Motivation	.32		
JAT Spatial 3-D	.33		
Ninth Grade			
Personal Usefulness	.12	Personal Usefulness	.56
General Usefulness	.15	Importance for "X" (Mother)	.59
Motivation (Father)	.18	JAT Synonyms	.61
JAT Number	.21	Confidence	.62
Attitude toward Success	.22	Motivation	.64
JAT Spatial 3-D	.24	Motivation (Mother)	.65
Motivation (Mother)	.25		
Male Domain (Mother)	.26		

*Only variables adding at least 1 percent to predicted variance are included

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indicate that a large percentage of the variance of mathematics achievement is accounted for by the predictor variables for both sexes and grades.

In Table 6 it is shown that non-cognitive variables predominate over cognitive variables as predictors of intended mathematics participation. It should be noted that the pattern of high correlations varies according to the sex and grade of students. In the case of males, especially ninth graders, very few variables correlate highly with intended participation, while cognitive variables seem to be almost irrelevant. Only Personal Usefulness has a substantial correlation with intended participation for ninth grade males. The predictive models for seventh and ninth grade males are given in Table 8 and the low squared multiple correlations (.33 and .26) reflect the above observations.

A different picture emerges for females. Several non-cognitive student variables correlate highly with intended participation for both grades, while some cognitive and the Importance for "X" (Father and Mother) Scales also correlate substantially with the dependent variable for ninth grade females. In Table 8 it is shown that five non-cognitive and one cognitive variable accounts for as much as 65 percent of the variance of ninth grade females' intended mathematics participation, while the squared multiple correlation for seventh grade females is only .41. For males as well as females, perceived personal usefulness of mathematics was the strongest predictor.

Discussion

The purpose of this study was to identify and explain the factors affecting mathematics participation and achievement during adolescence and, in particular, to find explanations for sex differences which typically occur from adolescence onwards in mathematics behaviour.

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Marked sex differences favouring males were found with regard to actual mathematics participation, as well as for intended mathematics participation, from as early as the seventh grade. No sex differences in overall mathematics achievement were found for early adolescents or adolescents, nor for twelfth graders in their final school mathematics examinations. Mathematics olympiad data and final school results, however, indicate substantial sex differences in favour of males at the upper end of the scale.

Spatial visualization could not be investigated as an explanation for sex differences in mathematics achievement when such differences were non-existent. However, sex differences in spatial visualization were found for the adolescent group only and substantial correlations between spatial abilities and mathematics achievement were found. It should be noted that other cognitive variables also correlated highly with achievement. Findings by other researchers that sex differences in mathematics achievement may be explained by sex differences in spatial visualization or mathematics course participation (Burnett, Lane & Dratt, 1979; Chipman & Thomas, 1985; Fennema & Sherman, 1977) could not be verified in this study, but remain feasible. The achievement tests used in this study did not allow for the investigation of possible sex differences with regard to certain branches of mathematics such as problem-solving.

Developmental changes do seem to occur in the period between early adolescence and adolescence which negatively affect the affective and attitudinal position of females with regard to mathematics, as well as their perception of the expectations and encouragement of significant others. This finding is borne out by the large number of significant differences between the sexes on the non-cognitive variables in the adolescent group, which indicate that males have more positive attitudes toward mathematics than females. Similar differences were not found for the younger students, except for students' perception of the personal

usefulness of mathematics. Another exception is that males, even fathers, are more inclined than females to stereotype mathematics as a male domain. Similar findings were reported by Fennema and Sherman (1978), Sherman and Fennema (1977) and Visser (1983b).

The influence of emotional, attitudinal, and social factors on the mathematics behaviour of adolescent females is clearly indicated by the results of correlational data and predictive models employing stepwise multiple regression procedures. In contrast to the results for males and seventh grade females, several non-cognitive variables correlate substantially with the mathematics achievement of ninth grade females. Furthermore, the intention of ninth grade females to continue their participation in mathematics was accurately predicted by social, affective and attitudinal variables ($\underline{R}^2 = .65$). Encouragement of parents seem to be a major influence on the mathematics behaviour of adolescent females. The decision of adolescent males to continue their participation in mathematics is to a large extent taken independently of the study variables.

The findings of this study confirm that adolescence is the critical period during which achievement patterns in mathematics are established, with almost inevitable implications for future vocational options.

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